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TR-65-209-2

TRAJECTORY VALIDATION FOR PROJECT APOLLO

April 9, 1965

Prepared by:

I. Bogner
V. S. Mummert
R. L. Wagner

Trajectory Analysis Department
Bellcomm, Inc.

Work Performed for Manned Space Flight, National Aeronautics and Space Administration, as part of Task 9 under Contract NASw-417.

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ABSTRACT

Trajectory validation is defined as the identification and checking of the specific trajectory data which have a direct effect on the conduct of a space mission. It is a part of the larger problem of validating all of the software connected with a mission and is especially closely related to the validation of guidance equations and software of the Mission Control Center. It is, however, different from most of the other software validation in that numbers rather than computer programs are being checked

Because the individual missions of the Apollo program are quite different, the identification of the specific trajectory quantities to be checked will be a constantly recurring part of the validation problem. This must be done during the early phases of preparing for each mission so that an effective last check can be made in the short time period just before the flight when final data are available. Trajectory validation is so closely intertwined with guidance validation that the two should be as closely coupled as is practical.

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1. INTRODUCTION

Trajectory validation is part of a quality control procedure toward certification of the software associated with a space mission. When properly implemented, it can provide the assurance that the prior computations necessary for the mission are a correct, complete and consistent set.

This report covers a general plan for trajectory validation in the Apollo project. It identifies generic categories of information to be checked and also specific examples for the lunar landing mission. More specific detailing of the validation procedure is an integral part of the validation of each mission trajectory.

2. TRAJECTORY VALIDATION IN PERSPECTIVE

The use of general purpose digital computers as part of operational hardware systems has developed rapidly over the past ten years. With this growth, the problem of producing satisfactory programs (software) has steadily gained recognition. The development of software has become more and more like the development of hardware and when professionally done it often involves specifications, drawings, models, formal checkout and quality control. The volatile nature of software has caused its development, management* and control to present special problems.

Guidance equation validation is an example of software quality control (of the on-board guidance software). Other examples in Apollo are validation of checkout software (such as for ACE) and the real time computer software of the Mission Control Center. Trajectory validation is different from any of the above in that numbers are being confirmed rather than computer programs. The term software frequently has been used to cover data as well as computer programs and in this context trajectory validation is part of software validation.

In common with guidance equation validation, there is a wide range of activity which is covered by the term trajectory validation. Two extremes will serve to illustrate:

A. Design Verification

This activity consists of studies leading to a general critique of the trajectory design.

B. Quality Control

This activity consists of checking specific quantities by well defined methods.

The terms Design Verification and Quality Control are widely employed in hardware development and will be used here whenever it is necessary to distinguish between the extremes of trajectory validation activities.

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*The general problem of software management in Apollo is being studied under NASA/BELLCOMM Task 22, Contract NASw-417 ("Management Procedures in Computer Programming for Apollo" Interim Report, November 30, 1964, Bellcomm, Inc.).

3. TRAJECTORY QUANTITIES TO BE VALIDATED (QUALITY CONTROL)

Trajectories are computed to satisfy many different needs and historically the tendency has been to provide copious printout. Perhaps this is, as some claim, for the purpose of satisfying very diverse requirements some of which are not anticipated before the computation. Whatever the reason, there are categories of information in the various printouts quite different in their use and quite different with respect to the impact of an error. It is suggested that there is at a minimum the following division of trajectory derived information:

A. Information which results in specific action and which has a direct effect on the conduct of the mission. An example is the velocity requirements leading to the fuel loading of the space vehicle.

B. Information which is of a general descriptive nature and which is not directly used in the conduct of the mission. Examples might be vehicle ground tracks or acceleration profiles.

The validation procedure should be appropriately fitted to each category of information. Guidance parameters and fuel loadings should be very carefully checked whereas more general information such as position and velocity histories can probably be checked on a sampled basis.

A validation procedure would be expected to benefit strongly from a process of evolution, however, initial specific proposals are outlined in the following paragraphs of this section. The details of the validation process will depend upon the type of mission. The lunar landing mission is used as an example on the assumption that its requirements will exceed those of the test missions.

3.1 Input Data

A very important part of the validation of trajectories is the checking of the assembled data from which the trajectory is derived. This includes the vehicle model, vehicle constraints, mission constraints and mission ground rules and objectives. Most of these inputs are explicitly covered by documents in the present project documentation plans. Checks should be made against these documents as well as other valid sources. Typical lists of input data for the lunar landing mission are contained in Appendix I.

3.2 Guidance Parameters

Among the most important trajectory derived quantities are the guidance parameters which make the guidance equations specific for the given mission. For the current Apollo guidance equations which are generally explicit* many of the parameters have strong physical significance.

Two possibilities for validating these guidance parameters are outlined:

A. Simulate a closed loop mission using the precomputed guidance parameters for the trajectory being validated and correct for any inaccuracies by making midcourse and other corrections as would be done in the actual mission. The validation rests on a simulated flight with position and velocity accuracies and fuel requirements within acceptable limits. This could be done as part of the guidance equation validation procedure but would impose certain requirements on the simulation to be used. It would require, for example, a complete trajectory simulation incorporating lunar and solar ephemerides thereby providing for continuity of the trajectory calculation through all phases of the mission.

B. Independently generate a guided trajectory using the same input data as for the one being validated. The guidance parameters are determined by successive iteration during the trajectory selection and optimization procedure. Validation is done by comparing the guidance parameters from the original and independently generated trajectory.

Of the two methods described above, A has the advantage that the dispersions due to the guidance parameter discrepancies are the quantities available for scrutiny. Allowable levels for these dispersions should be relatively easily determined. For method B acceptable tolerances on each of the guidance parameters must be developed and this may not be a trivial problem.

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*The term "explicit" refers to that class of guidance equations in which the desired end conditions are overt and in which the steering is continually recomputed to reach these end conditions rather than to return to a reference trajectory.

Primarily for purposes of providing perspective, many of the guidance parameters for the lunar landing mission are listed in Appendix II with the present concept of the guidance equations.

3.3 Propulsion Requirements

The fuel loadings for a specific mission are determined from the reference trajectory for that mission plus the results of error analysis. The reference trajectory directly provides the nominal ΔV requirements for the mission. Actually, the mission changes* somewhat as a function of launch time within a single launch window and also from day to day within that period in which a delayed launch might occur. The associated changes in fuel requirements can be quite significant especially if the launch windows are not all of the same type or if the lunar landing site is changed (in a preplanned fashion) during the launch period. The fuel loadings thus may reflect the requirements of several missions and may not be optimum for any one mission.

Complete validation of the adequacy of the fuel loadings must be done eventually, however, the nominal requirement is the only part which can be checked through trajectory validation. If error analysis results are available, the total requirement should be developed at the time of trajectory validation.

3.4 Time Histories and Events

The common concept of a trajectory is the computer printout of various time histories such as acceleration, velocity, position, vehicle attitude (during powered flight) and radar look angles. Many of these quantities are used in assembling an operational plan. With multiple choices of coordinate systems, derived secondary variables and units, it would be nearly impossible to check all of the possible quantities, but the more important ones must be checked at least on a sample basis. Better validation could be accomplished if the quantities needed could all be defined in advance and this should be vigorously encouraged.

A sample list of some of the more important quantities to be checked are included in Appendix III.

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*There will be, in effect, a family or continuum of trajectories to be validated for the lunar landing missions. The method of portraying the information may be more imaginative than simply providing a multiplicity of similar trajectories.

4. THE MECHANICS OF GENERATING THE VALIDATING TRAJECTORY

In the previous sections emphasis was placed on defining the type of trajectory information which should be checked. Some of the problems which are inherent in generating the trajectory to serve as a basis for this validation are discussed in this section.

Validation, to be at all significant, requires an "independent" computation of the mission trajectory. From this the specific quantities to be validated can be derived if not available as an automatic by-product of the basic computation. Two different approaches have been suggested for computing the validating trajectory. One method begins with the same input data, ground rules, constraints, trajectory shaping strategy and degrees of freedom (for optimization) as used for the original computation. A completely independent trajectory selection and optimization is done and the quantities to be validated are compared for the two trajectories. There is an obvious difficulty in this method in that two perfectly good trajectories may differ by fairly significant amounts in certain parameters. This phenomenon is likely to occur because the trajectory is selected in part through optimization techniques and the largest discrepancies can be expected in the parameters which have been optimized. For example, the service module fuel is minimized by adjusting the azimuth* of the lunar parking orbit plane within the limits allowed by the LEM plane change constraint. If the true optimum lies between the LEM limits the curve relating SM fuel and lunar parking orbit azimuth will have zero slope at this point. Independent optimizations very likely would result in significantly different inclinations if only because of the numerical granularity in the fuel computation or the limits which determine when the computer iteration is to stop. The tolerance on the optimum azimuth was empirically determined for an SM fuel granularity of 100 pounds (out of 37,000 pounds). For nine different landing sites well distributed over the area of interest to Apollo, the azimuth tolerance ranged from ±1° to ±3°. Much closer agreement than this is generally desirable in the validation.

A second method of computing the trajectory would use the input data and shaping parameters of the trajectory being validated. These shaping parameters are typically such things as steering orders (or guidance parameters) and values of the

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*The parking orbit plane must contain the landing site at the time of landing, but the direction (azimuth) from which the vehicle approaches is a free variable.

optimization variables which are a result of the original process of selecting a specific trajectory satisfying the constraints, ground rules etc. The open loop simulation of a trajectory using these data would be analogous to "dead reckoning" navigation from start to finish. The extent of the Apollo lunar landing trajectory is such that insignificant perturbations early in the mission are amplified to very large proportions in the terminal phases. This makes it impractical to establish the initial conditions from the trajectory being validated and to then simulate the mission in a forward direction with all steering orders as previously computed. Even though the initial conditions and shaping parameters are perfect, microscopic differences between computer simulations will guarantee the failure of this approach.

It is expected that the most practical trajectory computation method will start with an independent optimization and computation of the mission trajectory as in the first method outlined above. The trajectory being validated is judged against this independent computation to infer how nearly it approaches the optimum.* Next the optimization variables can be constrained to be those of the trajectory being validated and the individual trajectory segments retargeted with these additional constraints. The degree of correspondence between trajectories should be much improved if there are no rank errors in either one. The validation of all remaining trajectory derived parameters should be possible based on this second trajectory computation. The optimization variables which are candidates for being fixed in the second trajectory computation are as follows:

A. The inclination of the near earth portion of the return leg of the free return trajectory (translunar time of flight if free return is not used)

B. The inclination of the lunar parking orbit

C. The inclination of the near earth portion of the transearth leg of the trajectory

D. The true anomaly of the intersection of the lunar parking orbit plane and the transearth trajectory (different from zero where pre and post pericynthion injection is allowed)

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*It is not to be assumed that optimum trajectories are mandatory, however, if the trajectory is not optimum by a significant amount, there should be an adequate reason.

Experience may show that some of these need not be held fixed for satisfactory checks and, of course, alternative (but equivalent) variables may be defined to replace any of the above.

Having an independent trajectory computation, comparisons with the trajectory being validated are then conducted primarily in terms of the quantities for which the trajectory was computed in the first place.

5. SCHEDULE AND PROGRAM IMPACT ON TRAJECTORY VALIDATION

There is a schedule for the production of software for the Apollo missions including the test missions. The software end items and the required delivery dates have been defined as a result of planning work which has been going on for about a year. Table I is a copy of a schedule recently distributed through the Flight Mechanics Panel and it shows a very ambitious program of documentation* related to trajectories and guidance.

The immediate question is, "Which document or documents contain the trajectory to be validated?" There clearly is no answer, but item 38 of Table I (Operational Mission Trajectory Plan) probably comes closest of all the documents listed. One observation is that validation requires a defined product or end item to be checked. Another point is that there must be advanced preparation for validation and advance information on the critical content of these documents if validation is to be carried on as a parallel activity which does not disturb the documentation schedule. A third point is that the organization carrying out the original trajectory computation must be committed to participating in the validation program and cooperating in carrying it out. Without this it would be very difficult to do effective validation in the quality control sense.

The Apollo program will present validation problems characteristic of research and development endeavors. Specifically, procedures for trajectory validation (quality control in particular) will have to work the first time tried since much will be new for each mission. The more complicated and unique missions will generate requirements for trajectory data in an unscheduled and unpredictable fashion. The validation procedures adopted will have to keep up as well as possible in this unfriendly (for quality control) environment. In section 2, design verification was introduced as being the extreme opposite of quality control within the scope of trajectory validation. It is an earlier (in time) activity in the validation process and, because it is not a hard and fast procedure, it is better able to cope with a changing scene. During design verification familiarity with the trajectory is established and in the one to two year span between the preliminary mission trajectory and the actual flight the critical quantities and tolerances for

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*There are additional documents of similar type defined within each Center which do not appear in the Flight Mechanics Panel Schedule.

Table I**

MSC-MSFC INTERFACE DOCUMENTATION SCHEDULE (MONTHS REQUIRED PRIOR TO LAUNCH)

Document Title	Respon-sibility	Saturn - Apollo Mission						
		201, 202	204	205	206-502	503-504	505, 506	507-up
1. MSC Constraints	MSC			20+	23+	25+	27+	29+
2. MSFC Constraints	MSFC			20+	23+	25+	27+	29+
3. Preliminary Mission Constraints	MSC/MSFC			20+	23+	25+	27+	29+
4. MSC Preliminary Mission Profile	MSC		18	20	23	25	27	29
5. MSFC Preliminary Mission Profile	MSFC		18	20	23	25	27	29
6. Preliminary L/V Reference Trajectory	MSFC		17	19	22	24	26	28
7. Preliminary S/C Reference Trajectory	MSC		16	18	21	23	25	27
8. Preliminary Reference Trajectory	MSC/MSFC		16	17	20	22	24	26
9. Prelim. L/V Range Safety Traj. Plan	MSFC		14	16	19	21	23	25
10. Prelim. S/C Range Safety Traj. Plan	MSC		14	15	18	20	22	24
11. S/C Guidance Targeting Objectives	MSC		15	16	19	21	23	25
12. L/V Targeting Objectives Proposal	MSC		15	17	20	22	24	26
13. L/V Targeting Objectives Proposal	MSFC		15	17	20	22	24	26
14. L/V Targeting Requirements	MSFC/MSC		15	16	19	21	23	25
15. L/V Guidance Equations	MSFC		14	15	18	20	22	23
16. Prelim. Abort & Alt. Mission Studies	MSFC		13	15	18	19	21	22
17. L/V Prelim. Error Anal. (Closed Loop	MSFC		13	15	17	19	21	23
18. Spacecraft Guidance Equations	MSC		14	15	17	19	21	23
19. S/C Preliminary Error Analysis	MSC		14	15	17	19	21	23
20. MSC Mission Constraints	MSC		13	14+	16+	18	20	22
21. MSFC Mission Constraints	MSFC		13	14+	16+	18	20	22
22. Reference Mission Constraints	MSC/MSFC		12	14+	16+	18	19	20
23. L/V Reference Trajectory	MSFC	10	12	14+	16+	17	18	19
24. S/C Reference Trajectory	MSC	10	11	13	15	16	17	18
25. Reference Trajectory	MSC/MSFC	10	11	13	15	16	17	18
26. L/V Range Safety Trajectory Plan	MSFC			12	14	15	16	17
27. S/C Range Safety Trajectory Plan	MSC			11	13	14	15	16
28. L/V Guidance Error Analysis	MSFC	8	8	11	13	14	15	16
29. L/V Performance Analysis	MSFC	8	8	11	13	14	15	16
30. Det On-Board S/C G&N Error Anal.	MSC	7	7	10	10	11	12	12
31. Detailed MSFN Error Analysis	MSC	7	7	10	10	11	12	12
32. S/C Powered Flight Performance Anal.	MSC	7	7	10	10	11	12	12
33. Operational Mission Constraints	MSFC/MSC	6	6	4	4	4	4	4
34. L/V Range Safety Trajectory Plan	MSFC	2	2	4	4	4	4	4
35. S/C Range Safety Trajectory Plan	MSC	2	2	3	3	3	3	3
36. Operational L/V Flight Trajectory	MSFC	5	5*	4*	4*	4*	4*	4*
37. Operational S/C Flight Trajectory	MSC	4	4*	3*	3*	3*	3*	3*
38. Operational Mission Trajectory Plan	MSC/MSFC	3	3*	3*	3*	3*	3*	3*
39. L/V Oper Alt Mission & Abort Traj	MSFC	3	3	3*	3*	3*	3*	3*
40. S/C Oper Alt Mission & Abort Traj	MSC	3	3	3*	3*	3*	3*	3*
41. Alternate Mission and Abort Plan	MSC/MSFC	3	3	3*	3*	3*	3*	3*

*These documents are updated as necessary and contain the best available mission and trajectory data.

**Originally appeared as Table I, attachment to letter (PS3-M2309) from Co-Chairmen, MSC/MSFC Flight Mechanics Panel (undated but received 3/18/65).

that trajectory must be established. As the flight time approaches and the trajectory converges to the final issue these quantities can be checked in each new issue to avoid as much last minute work as possible. It is important that the final validation checks (quality control) be planned and documented in an orderly fashion for the obvious error rather than the esoteric error is the more likely to be overlooked just prior to the flight.

6. SUMMARY

Trajectory validation should be done for each of the missions of the Apollo project. The effort should extend from the time of the preliminary mission profile document to or slightly beyond the flight date. The early phases of the validation procedure should result in familiarity with the physical properties of the trajectories and a specific set of quantities which are to be checked for each new issue of the trajectory including the one just before the flight. The quantities to be checked should definitely include all trajectory derived data which can be identified as having a direct influence on the conduct of the mission. The specific identification of these data promises to be a major part of the validation task.

IB
1022-VSM-rg
RLW

I. Bogner

I. Bogner

V. S. Mummert

V. S. Mummert

R. L. Wagner

R. L. Wagner

BA-149A (8-64)

APPENDIX I

This appendix contains typical lists of trajectory input data required for a minimum simulation of an Apollo LOR lunar landing mission. As time goes on the list will change and grow somewhat as additional, important details of the mission sequence are determined and simulated. These lists are referenced in Section 3.1 and are included here only for the purpose of providing examples for those who are not aware of the magnitude or type of inputs required.

Vehicle Data

Launch Vehicle

1. S-IC initial weight
2. S-IC mass flow rate
3. S-IC sea level thrust
4. S-IC nozzle area
5. S-IC cross sectional area
6. S-II initial weight
7. S-II dry weight
8. S-II mass flow rate
9. S-II thrust
10. S-IVB initial weight
11. S-IVB dry weight
12. S-IVB mass flow rate
13. S-IVB thrust
14. Vertical rise duration
15. Time of S-IC center engine shutdown
16. Time of S-IC shutdown
17. Coast time between S-IC shutdown and S-II ignition
18. Time of LES jettison

19. Weight of LES
20. Time of interstage jettison
21. Weight of interstage
22. Coast time between S-II shutdown & S-IVB ignition
23. Drag table

Spacecraft

1. S/C initial weight
2. LEM initial weight
3. LEM ascent initial weight
4. Weight of two astronauts
5. S/C dry weight
6. LEM descent dry weight
7. LEM ascent dry weight
8. SM mass flow rate
9. SM thrust
10. LEM descent mass flow rate
11. LEM descent thrust
12. LEM ascent mass flow rate
13. LEM ascent thrust
14. LEM ascent RCS mass flow rate
15. LEM ascent RCS thrust
16. SM guidance allowances outbound
17. SM guidance and contingency allowances return
18. Altitude of LEM at beginning of rectilinear or constant attitude approach

19. Pitch angle on constant attitude approach
20. Throttle ratio from pitch-over to hover
21. Altitude and velocity at hover
22. Duration of ascent stage vertical rise
23. Altitude of perilune of Hohmann descent transfer orbit

Spacecraft During Entry

1. Weight of command module
2. Maximum L/D
3. Weight/drag-area ratio (ballistic number)
4. Reentry altitude
5. Drag table
6. Lift table

Mission Data

1. Launch date
2. Choice of one of two daily launch windows
3. Launch azimuth
4. Free-return inclination limits
5. Outbound trajectory: free return or unrestricted
6. Number of earth parking orbits (an integer)
7. Lunar landing site position
8. Maximum LEM plane change allowable
9. Number of lunar parking orbits before descent transfer orbit injection
10. Nominal lunar surface stay time

11. Number of lunar parking orbits after rendezvous
12. Maximum lunar surface stay time (contingency)
13. Maximum return flight time
14. Maximum equatorial inclination at return to earth
15. Earth reentry range
16. Earth landing site or area

Apollo Trajectory Standards

1. MSFN site locations
2. Astrodynamic constants
3. Earth atmosphere
4. Lunar, solar and planetary ephemerides (JPL tapes and equations)
5. Rigid body transformation for the moon (JPL equations)

APPENDIX II

This appendix contains a list of typical guidance parameters as the guidance is now envisioned for the lunar landing mission. It is included for perspective only as the detailed methods of implementing the guidance for the lunar landing mission are not yet completely decided. The guidance computers may have many more parameters (constants) in memory but they cannot be checked via trajectory validation. This list is referenced in section 3.2.

Phase	Guidance Parameters	Equivalent Number of Scalars
Launch to Orbit	Vertical rise time	1
	Gravity turn kick	1
	Pitch polynomial coefficients	5
	Isp for each stage	3
	Mass flow rates	3
	Estimated burning times for each stage	3
	Aiming azimuth polynomial coef.	5
	Orbit plane inclination polynomial coef.	5
	Orbit plane descending node polynomial coef.	5
	Cutoff velocity magnitude	1
	Flight path angle	1
	Altitude	1
	Total	34
Translunar Injection (MIT Backup)	Position Target Vector	3
	Semi-major axis	1
	True anomaly of injection	1
	Total	5

Phase	Guidance Parameters		Equivalent Number of Scalars
Translunar Miscourse #1	Target position vector		3
	Time of correction		1
	Time to target		1
		Total	5
Translunar	Pericynthion distance		1
	Normal to the plane		3
	Time of correction		1
		Total	5
Translunar Miscourse #3 (Free return)	Velocity at lunar sphere of influence		3
	Time of correction		1
		Total	4
Hohmann	Radius of pericynthion		1
	Vector normal to plane		3
	Semi-major axis		1
		Total	5
Lunar Descent (only Phase II conditions are specified)	Normal to the plane		3
	Terminal altitude		1
	Terminal sink rate		1
	Terminal down range position		1
	Terminal down range velocity		1
	Initial sink rate		1
	Thrust direction		1
	Duration of Phase II		1
		Total	10

Phase	Guidance Parameters	Equivalent Number of Scalars
LEM Ascent	Lift-off time	1
	Vertical rise time	1
	Burnout altitude	1
	Burnout angular momentum	3
	Burnout radial velocity	1
	Total	7
LEM Midcourse	Target (CM position) vector at fixed time of arrival	3
	Time of correction	1
	Total	4
Rendezvous	Range-range rate schedule (analytic function or table)	?
	Total	
Transearth Injection	Vector velocity	3
	True anomaly of ignition	1
	Total	4
Transearth Midcourse #1	Time of correction	1
	Perigee altitude	1
	Landing site	3
	True anomaly of landing site vector extended	1
	Total	6
Transearth Midcourse #2	same	same
Transearth Midcourse #3	same	same

Phase	Guidance Parameters		Equivalent Number of Scalars
Reentry*	Latitude		1
	Longitude		1
		Total	2

*There are approximately 50 gain constants which will be checked during guidance equation validation since they are primarily for stability of operation rather than trajectory shaping.

APPENDIX III

This appendix contains lists of quantities to be checked as part of the general validation of the trajectory time histories. How big this list should be or which quantities should be checked is a matter of judgment. Some quantities are checked as inputs and again as they appear in the printout. These lists are referenced in section 3.4.

Event Checks

1. Time and magnitude of maximum dynamic pressure
2. Mission time of the beginning of each of the eight powered flight maneuvers
3. Event time of the termination of each powered flight maneuver (duration)
4. Weight before and after powered flight
5. Characteristic velocity (ΔV) for each powered flight
6. Time of jettisoning the LES and the SIC/SII interstage
7. Times and magnitudes of acceleration peaks during each major burn and entry

Constraint Checks

1. Maximum angle of attack while in the atmosphere
2. Pilot visibility during LEM descent
3. LEM-CSM line of sight
4. Lunar lighting during landing and while on the surface
5. Continuous LEM abort capability for maximum contingency stay time (plane change limit never exceeded)
6. Service Module capability for returning to earth from any lunar parking orbit during the nominal and contingency stay times.
7. Earth-vehicle-sun angle during the transearth trajectory (on-board navigation)
8. Heating during entry

Geometric Checks

1. Plane change at:

   Translunar injection

   Deboost into lunar parking orbit

   Rendezvous (may be elsewhere depending on LEM ascent strategy)

   Transearth injection

2. Altitude of:

   Pericynthion of approach hyperbola

   Pericynthion of return hyperbola

   Lunar parking orbit

   Descent transfer orbit apocynthion and pericynthion

   Ascent transfer orbit(s) apocynthion and pericynthion

   Earth parking orbit

   Transearth perigee

   Translunar perigee

3. Earth equatorial inclination of:

   Translunar elipse

   Earth parking orbit

   Transearth elipse

4. Lunar equatorial inclination of:

   Translunar hyperbola

   Transearth hyperbola

   Lunar parking orbit

   Descent transfer orbit

   Ascent transfer orbit

5. Position of the lunar landing site with respect to the lunar parking orbit plane at the time of landing.

6. Position of the earth landing site with respect to the prescribed area (an input quantity)